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Impact of platform switching on inter-proximal bone levels around short implants in the posterior region; 1-year results from a randomized clinical trial

Gerdien Telleman[1,2], Gerry M. Raghoebar[1], Arjan Vissink[1] and Henny J. A. Meijer[1,2]

[1]Department of Oral and Maxillofacial Surgery and Maxillofacial Prosthetics, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands; [2]Department of Fixed and Removable Prosthodontics, Centre for Dentistry and Oral Hygiene, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands

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Abstract

Aim: To assess the outcome of short implants (8.5 mm) supplied with a conventional platform-matched implant-abutment connection or a platform-switched design.

Materials and Methods: Eighty patients with one or more missing teeth in the posterior zone were randomly assigned to be treated with implants with either a conventional (control) or a platform-switched (mismatch 0.35–0.40 mm) implant-abutment connection (test). Follow-up visits were conducted 1 month and 1 year after placing the implant crown. Outcome measures were inter-proximal bone loss, using standardized peri-apical radiographs, implant survival, clinical parameters and patients' satisfaction.

Results: One year after loading, inter-proximal bone loss around test implants (0.51 ± 0.51 mm) was significantly less than around control implants (0.73 ± 0.48 mm) ($p = 0.011$). Moreover, bone loss was less around 1 *versus* 2 adjacent implants ($p = 0.001$), in both the test (0.29 ± 0.36 *versus* 0.71 ± 0.55 mm) and control (0.46 ± 0.42 *versus* 0.88 ± 0.45 mm) group. With regard to implant survival, clinical parameters and patients' satisfaction no differences were observed between the test and control group.

Conclusion: This study suggested that crestal bone resorption may be reduced by platform switching. One year after loading, inter-proximal bone levels were better maintained at implants restored according to the platform switching concept.

Key words: dental implant; implant-abutment connection; inter-proximal bone level; patients' satisfaction; platform switching; short implants; survival

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Conflict of interest and source of funding statement

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From the moment the healing abutment is placed and the implant is exposed to the oral environment biologic width formation starts. A mucosal attachment of a certain minimum vertical dimension (3–4 mm) is formed and as a consequence crestal bone resorption may take place (Berglundh & Lindhe 1996, Hermann et al. 2001a,b). Whether or not crestal bone resorption will occur depends, amongst others, on the presence of a microgap between implant and abutment and on the location of this microgap in relation to level of the crestal bone. One-piece implants (no microgap) and implants placed above the alveolar crest have been shown to prevent crestal bone resorption (Hermann et al. 2001a, Todescan et al. 2002, Broggini et al. 2006, Cochran et al. 2009). The implant-abutment connection is thought to be an important factor regarding peri-implant bone loss as also the highest number of inflammatory cells has been observed at the implant-abutment interface (Broggini et al. 2006).

An alternative implant-abutment configuration involves a non-matching diameter for the implant and abutment. In, so called, platform-switched implants the diameter of the abutment is less than the diameter of the implant, resulting in a horizontal offset at the top of the implant that separates the crestal bone and the connective tissue from the interface. Early results of these platform-switched implants showed no changes in peri-implant bone levels, contrary to standard platform-matched implants (Wagenberg & Froum 2010). Next, several hypotheses were posed to explain the rationale behind the concept of platform switching for crestal bone preservation. The biomechanical rationale proposed that by platform switching the stress-concentration zone (from the forces of occlusal loading) is directed from the crestal bone-implant interface to the axis of the implant and so reduces the stress level in the cervical bone area (Maeda et al. 2007). Cochran et al. (2009) showed that placing the implant-abutment connection below the crestal bone level may cause bone resorption to re-establish the biologic width. Following this theory, platform switching medializes the microgap and the dimension of the biologic width. A horizontal mismatch of 0.3 mm was found to decrease the vertical dimension of the junctional epithelium (Becker et al. 2009, Farronato et al. 2012). Another hypothesis concerned the role of inflammatory cell infiltrate at the implant-abutment connection. The presence of peri-implant microbiota was suggested to influence crestal bone resorption by maintaining the inflammatory cell infiltrate within the implant-abutment connection (Ericsson et al. 1995, 1996, Broggini et al. 2006). However, no association was found between crestal bone resorption and peri-implant microbiota at platform-matched and platform-switched implants (Canullo et al. 2010a).

Pre-clinical data of Cochran et al. (2009) showed minimal histological bone loss of platform-switched implant. The pre-clinical data were in contrast with the data described by Becker et al. (2007, 2009) who concluded that platform switching may not be of crucial importance for maintenance of the crestal bone level. The systematic review of Atieh et al. (2010) concluded that marginal bone loss around platform-switched implants was significantly less compared with platform-matched implants. Both implant-abutment connections were reported to result in very different crestal bone resorptions (0.021–0.99 mm for platform-switched and 0.101–1.67 mm for platform-matched implants). This large variation in results was thought to be due to the use of different implant diameters, mismatches and implant systems (Hürzeler et al. 2007, Cappiello et al. 2008, Canullo et al. 2009, 2010b, Crespi et al. 2009, Kielbassa et al. 2009, Prosper et al. 2009, Trammell et al. 2009, Vigolo & Givani 2009, Enkling et al. 2011). Moreover, three of the 10 included studies reported no differences in bone level changes between the platform concepts tested (Crespi et al. 2009, Kielbassa et al. 2009, Enkling et al. 2011).

Short implants (<10 mm in length) are increasingly used as there is fair evidence that short implants can be placed successfully in the partially edentulous patient, but with a tendency towards an increasing survival rate per implant length (Telleman et al. 2011a). So, especially in short implants it is important to preserve peri-implant bone. However, short implants might be expected to develop a greater maximum compressive stress in their coronal region in comparison with longer implants, which could lead to bone microfracture and crestal bone resorption (Hagi et al. 2004).

To our knowledge there is very limited evidence regarding the effect of platform switching on implants shorter than 10 mm in length in partially edentulous patients (Trammell et al. 2009). Therefore, the aim of this study was to compare the outcome of short implants (8.5 mm in length), provided with either a platform-matched implant-abutment connection or a platform-switched implant-abutment connection, placed in the posterior region of partially edentulous patients.

Materials and Methods

Patients

Partially edentulous patients referred to the department of Oral and Maxillofacial Surgery (UMCG, the Netherlands) for implant therapy, were considered for inclusion if they fulfilled the following criteria:

- At least 18 years of age;
- Capable of understanding and giving informed consent;
- One or more missing teeth being a (pre)molar in the maxilla or mandible;
- At the place of the future implant a maximum of 10 mm bone in vertical dimension and a minimum of 8 mm in horizontal dimension available.

Exclusion criteria were:

- Medical and/or general contraindications for the surgical procedures [ASA score $\geq$ III (Smeets et al. 1998)];
- Presence of active clinical periodontal disease in the dentition as expressed by probing pocket depths $\geq$ 5 mm and bleeding on probing;
- Presence of peri-apical lesions or any other abnormalities or infections at the implant site as determined on a radiograph;
- Smoking;
- A history of radiotherapy to the head and neck region.

Study design

This was a randomized clinical trial with two parallel groups. The study was approved by the Medical Ethical Committee of the University Medical Center Groningen (ABR NL37453.042.11). Before enrolment, written and verbal information was given to the patients and written informed consent was obtained.

Two different implant-abutment connections were studied on implants with a length of 8.5 mm. The platform-switched implants (Certain Prevail; Biomet 3i, Palm Beach Gardens, FL, USA) used in the test group had a horizontal mismatch of 0.35 and 0.40 mm, respectively, for the implants with a diameter of 4 and 5 mm. In a vertical dimension, the implant-abutment connection lied 0.09 and 0.11 mm, for implants with a diameter of 4 and 5 mm, respectively, above the implant shoulder (Fig. 1a). The control implants (XP Certain; Biomet 3i) had the same dimensions as the platform-switched implants except for the implant-abutment connection, which was platform-matched (Fig. 1b). Both implant types had an extended platform and a full dual-acid etched surface.

A specifically designed locked computer software program was used to randomly assign patients to one of the two study groups. Randomization by minimization (Altman 1991) was used to balance the possible prognostic variables [gender, age (≤ 50, >50 years), location of the implant site (maxilla, mandible), tooth or teeth to replace (premolar, molar, premolar & molar), number of implants to be placed (1, 2 or more)] between the two treatment groups. An investigator with no clinical involvement in the trial informed the surgeon, who inserted the implants, about the allocation result on the day of surgery, just before implant surgery was started. The prosthodontist was informed about the allocation result before the impression of the healing abutment was made. The surgeon and prosthodontist could not be blinded for the allocation result as they could see by the inner colour of the implant whether it was a test or control implant.

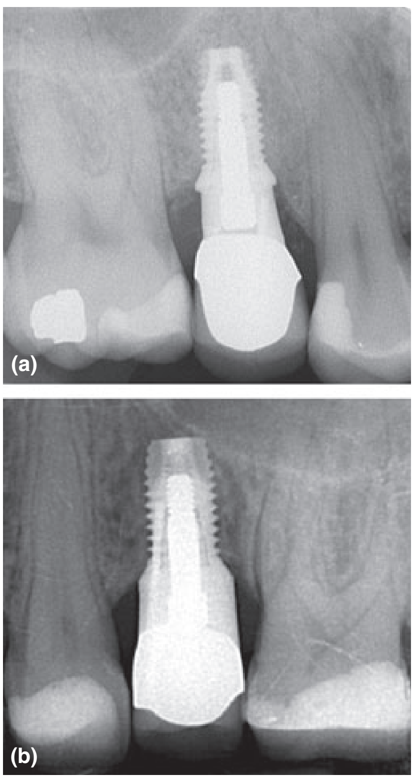

Fig. 1. (a) A radiograph of a test implant (Osseotite Certain Prevail, Biomet 3i). (b) A radiograph of a control implant (Osseotite XP Certain, Biomet 3i).

Interventions

All implants were placed in healed sites, i.e. at least 3 months after tooth removal allowing the extraction site to have healed. Implants were placed and restored according to the protocol described in detail by Telleman et al. (2011b). Briefly, the incision was made on top of the alveolar crest and a surgical template was used. The implant shoulder was placed at bone level, both mesial and distal even with the alveolar crest, if necessary the bone was flattened. The distance between the implant and the neighbouring teeth was at least 1.5 mm, the distance between two implants was at least 3 mm. On this implant, a coded healing abutment (Encode®; Biomet 3i) with a height of 4 mm was placed to develop an emergence profile. Next, if any, implant dehiscences or fenestrations at the buccal side of the implant were covered with autogenous bone chips collected during implant bed preparation and anorganic bovine boss (Bio-oss®; Geistlich Pharma AG, Wolhusen, Switzerland) overlaid with a collagen membrane (Bio-Gide®; Geistlich Pharma AG). Finally, the wound was closed with sutures (Vicryl® 3–0; Johnson & Johnson, Brunswick, NJ, USA). Two weeks following implant surgery the sutures were removed. Three months after implant placement, seating of the healing abutment was evaluated and impressions were made. The healing abutment was scanned from the cast and an individualized abutment was milled. The abutment was placed with 20 Ncm and the metal ceramic crown was cemented (GC Fuji 1; GC Europe NV, Leuven, Belgium).

All surgical procedures were performed by a single experienced oral and maxillofacial surgeon. Six experienced prosthodontics performed the prosthetic procedure.

Outcome measures

The primary outcome measure was the mean inter-proximal bone level change (mesial and distal sides combined) from the time of implant placement (T_{0m}) to 1 year after placing the crown on the implant; which is 16 months after placing the implant (T_{16m}) as measured on standardized radiographs. Secondary outcome measures were implant survival, changes in marginal soft tissue-level of the implant and the neighbouring teeth and patients' satisfaction. All measurements were performed by one and the same examiner. To assess the reliability of the radiographic examination, this examiner was assisted by a second examiner. The operationalization of the variables is described below.

Radiographic assessments

Before implant placement (T_{pre}), directly after implant placement (T_{0m}), 1 month after the placement of the implant crown, which is 5 months after placing the implant (T_{5m}) and 1 year after placing the implant crowns, which is 16 months after placing the implant (T_{16m}) digital peri-apical radiographs (Planmeca Intra X-ray unit; Planmeca, Helsiniki, Finland) were taken using a paralleling technique. For each patient an individualized X-ray holder was made to standardize radiographs. The calibration, using specially designed computer software (Biomedical Engineering, UMCG, the Netherlands) was carried out in the vertical plane for each radiograph, by using the known distance of several threads (Sewerin 1990). To assess the reliability of the radiographic examination 30 radiographs of 20 patients (10 from each study group) were assessed by two examiners.

Clinical assessments

Pre-operatively (T_{pre}), 1 month (T_{5m}) and 1 year (T_{16m}) after the placement of the implant crowns, the soft-tissue around the implants and their neighbouring teeth were clinically examined using the following clinical parameters:

- Plaque Index (Mombelli et al. 1987);
- Sulcus Bleeding Index (Mombelli et al. 1987);
- Gingival Index (Löe & Silness 1963);
- Presence of dental calculus;
- Sulcus probing pocket depth: using a manual periodontal probe (Williams Colour-Coded Probe; Hu-Friedy, Chicago, Il, USA).

Before the incision was made, the mucosa thickness was assessed by applying a periodontal probe through the mucosa at the spot where the implant would be placed.

Microbiological assessments

To analyse the composition of the subgingival plaque, pre-operatively an anaerobic culture test was conducted. In each quadrant of the dentition the deepest pocket was selected for microbiological sampling. After gentle air-drying, two consecutive sterile paper points were inserted to the depth of the pockets and left in place for 10 s. Paper points from all four selected periodontal sites were pooled in 2.0 ml of reduced transport fluid (RTF) (Syed & Loesche 1972). The presence and proportions of Aggregatibacter actinomycetemcomitans, Porphyromonas gingivalis, Prevotella intermedia, Bacteroides forsythus, Peptostreptococcus micros, Fusobacterium nucleatum and Campylobacter rectus were assessed. The analyses were performed by the laboratory of the department Oral Microbiology (UMCG, the Netherlands) as described in the study of Heydenrijk et al. (2002).

Patients' satisfaction

Patients' satisfaction was assessed using a self-administered questionnaire to be completed at T_{pre} and T_{5m}. The questionnaire compromised of questions or statements that could be answered on a five-point rating scale ranging from "very dissatisfied" and "not in agreement" (score 1) to "very satisfied" and "in agreement" (score 5). Topics were aesthetics, function and treatment procedure. Furthermore, patients were asked to mark their overall satisfaction about their mouth in which they missed teeth, which were replaced by implants, at T_{pre} and T_{5m} on 10-point rating scale from 0 to 10, in which 10 is the highest score.

Statistical analysis

Sample size was calculated using G*power version 3.1 (Faul et al. 2009). As there was no data in the literature of the mean marginal bone loss of short platform-matched implants, it was assumed that a mean marginal bone loss of 1.0 ± 0.5 mm would occur, from implant placement to 16 months thereafter, as the maximum marginal bone loss is seen up to 1.5 mm to the first implant thread. We considered 0.5 mm of radiographic marginal bone loss as a relevant difference between study groups, with an expected standard deviation of 0.75 mm. With a one-sided significance level of 5% and a power of 95%, a minimum of 36 patients per group was required, if one implant per patient was placed. A total of 72 patients for both groups would be needed, the total number of patients was set to at least 80 to deal with withdrawal.

To assess the inter-observer agreement for the continuous variables of the inter-proximal bone level changes (scored on peri-apical radiographs) two way random models were used to calculate the intra-class correlation coefficient.

To see whether the data were normally distributed the frequency distribution was plotted in a histogram. To test whether the result from the frequency analyses differed significantly from a normal distribution Kolmogorov–Smirnov and Shapiro–Wilk tests were done. For between groups comparisons of normally distributed variables, *t*-tests were used. Variables that were not normally distributed were statistically explored using Mann–Whitney tests.

Pearson correlation coefficients were used to assess whether the observed inter-proximal bone level change was dependent on the possible confounders implant location, implant diameter, result of the microbiological culture, mucosal thickness before placement and type of bone (Lekholm & Zarb 1985). Wilcoxon Signed Rank tests were used for changes in patients' satisfaction before and after the implant treatment.

In all analyses, expect for patients' satisfaction the statistical unit was an implant and for all analyses a significance level of $p < 0.05$ was chosen. Data were analysed using the Statistical Package for Social Sciences (version 16.0; SPSS Inc, Chicago, Il, USA).

Results

Patients

Between November 2005 and December 2009 a total of 80 (39 control group, 41 test group) patients were included in this trial. Baseline patients and treatment characteristics are listed in Table 1. In the control group, one implant had a dehiscence-type defect. In test group, one implant had a fenestration-type defect, as both reported in Table 1. These two patients (and two implants) were excluded from statistical analysis as the defects might influence the inter-proximal bone level changes. There were no drop-outs and all patients attended the follow-up visits, thus, data from 78 patients were available for statistical analysis. The control group consisted of 38 patients in which 58 implants were placed, the test group consisted of 40 patients in which 55 implants were placed.

Inter-proximal bone-level changes

The intra-class correlation coefficient for average measures was 0.867 for the radiographic inter-observer agreement (Cronbach's Alpha = 0.867), which can be interpreted as almost perfect agreement (Viera & Garrett 2005).

Figure 2a and b show the frequency distributions of the mean inter-proximal bone loss of the platform-matched and -switched

Table 1. Baseline characteristics of the patients

Variable	Platform-matched implant-abutment connection (control group; n = 39)	Platform-switched implant-abutment connection (test group; n = 41)
Mean age ± SD and range (years)	51.6 ± 10.60 (27–67)	48.0 ± 13.8 (18–70)
Female/male ratio	27/12	26/15
Implant position:		
Maxillary ($P_1/P_2/M_1/M_2$)	29 (3/12/13/1)	24 (2/8/13/1)
Mandibular ($P_1/P_2/M_1/M_2$)	30 (1/8/17/4)	30 (1/11/17/1)
Implant diameter:		
4.1 mm	35	40
5.0 mm	24	16
Number of implants to be placed in a patient:		
1	21	27
2 or more	18	14
Microbiology (before implant placement):		
Within normal range	16	17
Porphyromonas gingivalis >0.0%	1	0
Peptostreptococcus micros >3.0%	10	12
Fusobacterium nucleatum >3.0%	6	4
Combination of bacteria out of normal range	4	5
Culture was non-conclusive	2	3
Cause of tooth loss:		
Persistent apical periodontitis	13	17
Combined periodontic-endodontic lesion	1	0
Periodontal disease	4	3
Fracture	8	7
Dental caries	10	8
Congenitally missing tooth	2	3
Unknown	0	1
Mucosal thickness at the implant site before placement (%):		
1 mm	0.0	9.3
2 mm	64.7	46.5
3 mm	33.3	34.9
4 mm	2.0	9.3
Bone type (Lekholm & Zarb 1985):		
1	0.0	0.0
2	38.7	36.8
3	48.4	47.4
4	12.9	10.5
Implant dehiscence or fenestration:	1	1

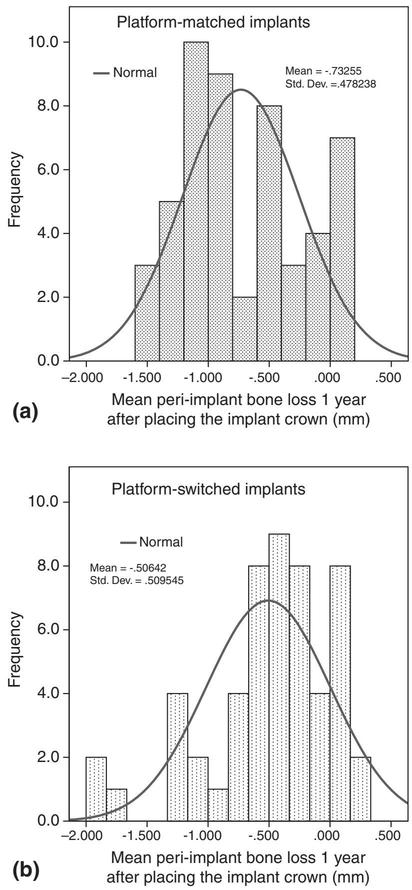

Fig. 2. (a) Frequency distribution of mean inter-proximal bone loss of implants supplied with a platform-matched implant-abutment connection. The distribution differs significantly from a normal distribution and shows a negative kurtosis. [$D(54) = 0.113$, $p = 0.113$, $W(54) = 0.941$, $p = 0.013$]. (b) Frequency distribution of the mean inter-proximal bone loss of implants supplied with a platform-switched implant-abutment connection. The distribution differs significantly from a normal distribution and shows a negative kurtosis. [$D(52) = 0.129$, $p = 0.028$, $W(52) = 0.909$, $p = 0.001$].

implants. Bone loss was significantly less around platform-switched implants, both 1 month and 1 year after loading (Table 2). When comparing inter-proximal bone loss in cases provided with one and two or more implants, a similar tendency was observed (Table 2).

Clinical outcome

Four of 58 implants in the control group were lost (survival rate 93.1%); three before loading and one 11 months after loading. In the test group, three of 55 implants were lost before loading (survival rate 94.5%). The mean probing pocket depth around the implants did not significantly increase between T_{5m} and T_{16m} (Table 2). Also no between-group differences in clinical parameters plaque accumulation, bleeding tendency, gingiva index (Table 3) were observed. The adjacent teeth of the platform-switched implants showed significant more presence of dental calculus before implant placement, 1 month and 1 year after placing the crown (Table 3).

Confounders

Crestal bone resorption is significantly ($p = 0.001$) higher as two or more adjacent implants were placed, when compared with single implants. So, the number of implants placed is an important confounder in crestal bone resorption. The thought confounders implant location, implant diameter, microbiological status, mucosal thickness and type of bone apparently played no significant role.

Patients' satisfaction

Feelings of shame and of visibility of being partial edentulous clearly decreased as well as that patients' self-confidence increased (Table 4). Patients were especially satisfied

Table 2. Changes in inter-proximal bone level and pocket probing depths at implant and tooth sides from baseline to 16 months. Negative results in implant bone-level changes indicate inter-proximal bone loss and positive results in pocket probing depth changes indicate enlarged peri-implant pockets

	T_{0m}–T_{5m}		T_{5m}–T_{16m}		T_{0m}–T_{16m}	
All implants	Platform-matched (n = 55)	Platform-switched (n = 52)	Platform-matched (n = 54)	Platform-switched (n = 52)	Platform-matched (n = 54)	Platform-switched (n = 52)
Inter-proximal bone-level changes (mm)	−0.70(±0.48)*	−0.48 (±0.46)*	−0.03 (±0.30)	−0.03 (±0.25)	−0.73 (±0.48)§	−0.51 (±0.51)§
One implant	T_{0m}–T_{5m}		T_{5m}–T_{16m}		T_{0m}–T_{16m}	
	Platform-matched (n = 19)	Platform-switched (n = 25)	Platform-matched (n = 18)	Platform-switched (n = 25)	Platform-matched (n = 18)	Platform-switched (n = 25)
Inter-proximal bone-level changes (mm)	−0.38(±0.45)	−0.27 (±0.32)	−0.06 (±0.29)	−0.02 (±0.25)	−0.46 (±0.42)†	−0.29 (±0.36)†
Pocket probing depth changes (mm)						
Implant	–	–	−0.22 (±1.09)	−0.02 (±0.57)	−0.22 (±1.09)	−0.02 (±0.57)
Tooth mesially of the implant	−0.10 (±0.51)	−0.02 (±0.46)	0.06 (±0.50)	−0.03 (±0.54)	−0.04 (±0.44)	−0.08 (±0.54)
Tooth distally of the implant	0.04 (±0.49)	0.08(±0.84)	0.06 (±0.60)	0.03 (±0.53)	0.10 (±0.67)	0.13 (±0.84)
Two or more implants	T_{0m}–T_{5m}		T_{5m}–T_{16m}		T_{0m}–T_{16m}	
	Platform-matched (n = 36)	Platform-switched (n = 27)	Platform-matched (n = 36)	Platform-switched (n = 27)	Platform-matched (n = 36)	Platform-switched (n = 27)
Inter-proximal bone-level changes (mm)	−0.89 (±0.39)	−0.67 (±0.48)	−0.01 (±0.30)	0.04 (±0.25)	−0.88 (±0.45)#	−0.71 (±0.55)#
Pocket probing depth changes (mm)						
Implant	–	–	0.18 (±0.50)	0.00 (±0.73)	0.18 (±0.50)	0.00 (±0.73)
Tooth mesially of the implant	−0.03 (±0.43)	0.10 (±0.45)	0.00(±0.43)	0.00 (±0.60)	−0.03 (±0.39)	0.10 (±0.63)
Tooth distally of the implant	0.38 (±0.18)	0.20 (±0.60)	0.44 (±0.66)	−0.10 (±0.52)	0.63 (±0.48)	0.10 (±0.40)

For between groups comparisons:
*p = 0.011
§p = 0.010
†p = 0.119
#p = 0.075

about their increased ability to chew, and about the colour and the form of the crown. Most patients were satisfied with the colour and form of the mucosa; others were indifferent about this particular subject. No differences were observed between the groups.

Discussion

This trial showed that 16 months after implant placement, crestal bone resorption was significantly less around short implants provided with a platform-switch, while with regard to implant survival, clinical parameters and patients' satisfaction both designs showed similar favourable results. A difference of 0.22 mm in radiographic bone preservation might not be clinically relevant, but a reduction in bone resorption of 30% (37% around single implants, 19% around two adjacent implants) is interesting, especially around single implants striving for perfection. The crestal bone resorption around platform-switched implants resembled the mean resorption as reported in the systematic review and meta-analysis of Atieh et al. (2010) on longer implants. Atieh et al. (2010) also did not detect a statistically significant difference in implant survival between the two platform designs. Furthermore, implant survival rates were lower than the survival rates reported for 8.5 mm implants (98.8%; 95% CI: 98.2–99.6%) in the systematic review of Telleman et al. (2011a). A reason for the lower survival rates in the study could be the number of implants placed in the maxilla as one of the conclusions of the review to short implants was that the failure rate of studies performed in the maxilla was 0.010 implants/year compared with 0.003 in the mandible. Another reason might be due to the fact that in the systematic review, also results of studies were included in which short implants could be splinted to longer implants. The reason could be that the implants used had an extended platform for which the use of countersink was needed for implant placement, this might have

Table 3. Clinical parameters of implants and adjacent teeth

Clinical parameters	% at T_{pre}		% at T_{5m}		% at T_{16m}	
	Platform-matched (n = 58)	Platform-switched (n = 55)	Platform-matched (n = 55)	Platform-switched (n = 52)	Platform-matched (n = 54)	Platform-switched (n = 52)
Implant Plaque Index [1]						
score 0, no detection of plaque	–	–	90.7	81.5	81.5	69.8
score 1, plaque on probe	–	–	9.3	18.5	16.7	26.4
score 2, plaque seen by naked eye	–	–	0	0	1.9	3.8
score 3, abundance of soft matter	–	–	0	0	0	0
Implant Bleeding Index[1]						
score 0, no bleeding	–	–	55.6	51.9	63.0	49.1
score 1, isolated bleeding spots	–	–	42.6	46.3	35.2	45.3
score 2, confluent line of blood	–	–	1.9	1.9	1.9	5.7
score 3, heavy or profuse bleeding	–	–	0	0	0	0
Implant Gingival Index[2]						
score 0, normal mucosa	–	–	96.2	88.9	96.3	90.6
score 1, mild inflammation	–	–	3.8	11.1	3.7	9.4
score 2, moderate inflammation	–	–	0	0	0	0
score 3, severe inflammation	–	–	0	0	0	0
Implant dental calculus						
score 0, no dental calculus	–	–	100	100	100	98.1
score 1, dental calculus present	–	–	0	0	0	1.9
Adjacent teeth Plaque index[1]						
score 0, no detection of plaque	58.6	52.3	76.8	66.2	79.6	69.8
score 1, plaque on probe	36.2	36.9	23.2	30.8	20.4	27.0
score 2, plaque seen by naked eye	5.2	10.8	0	3.1	0	3.2
score 3, abundance of soft matter	0	0	0	0	0	0
Adjacent teeth Bleeding index[1]						
score 0, no bleeding	82.8	71.2	83.6	78.5	90.6	84.1
score 1, isolated bleeding spots	17.2	25.8	16.4	20.0	9.3	15.9
score 2, confluent line of blood	0	3.0	0	1.5	0	0
score 3, heavy or profuse bleeding	0	0	0	0	0	0
Adjacent teeth Gingival Index[2]						
score 0, normal mucosa	96.6	87.7	98.2	89.2	98.1	96.8
score 1, mild inflammation	3.4	12.3	1.8	10.8	1.9	3.2
score 2, moderate inflammation	0	0	0	0	0	0
score 3, severe inflammation	0	0	0	0	0	0
Adjacent teeth dental calculus						
score 0, no dental calculus	91.4*	75.4*	94.6§	80.3§	89.1♯	71.9♯
score 1, dental calculus present	8.6*	24.6*	5.4§	19.7§	10.9♯	28.1♯

1(Mombelli et al. 1987).
2(Löe & Silness 1963).
Significant difference between control and test group.
*p = 0.019
§p = 0.020
♯p = 0.023

Table 4. Patients' satisfaction

	$T_{pre\%}$ in agreement		$T_{5m\%}$ in agreement	
	Platform-matched (n = 38)	Platform-switched (n = 40)	Platform-matched (n = 38)	Platform-switched (n = 40)
Feelings				
Presence of shame	21.6	23.1	2.7*	0*
Self-confidence decreased	18.9	7.7	0*	0*
Self-confidence increased	5.4	5.1	43.2 *	30.7*
Visible being partial edentulous	43.2	41.1	0*	0*
Function				
Evade eating with the edentulous zone/implant	56.7	53.8	0*	0*
The ability to chew is decreased	64.8	53.8	2.7*	0*
The ability to chew is increased	5.4	2.6	94.6*	92.3*
Implant does influence the speech	–	–	2.7	2.6
Implant does influence the taste	–	–	5.4	7.7
Aesthetics				
Satisfied with the colour of the crown	–	–	82.7	94.2
Satisfied with the form of the crown	–	–	86.5	92.3
Satisfied with the colour of the mucosa around the crown	–	–	75.8	70.6
Satisfied with the form of the mucosa around the crown	–	–	79.3	73.6
Overall satisfaction (0–10)	5.3 ± 2.1	5.6 ± 1.4	9.3 ± 0.9*	9.1 ± 0.9*

*significantly improved compared with pretreatment values (p = 0.00–0.001).

led to less initial implant stability (Renouard & Nisand 2006).

Crestal bone resorption was significantly higher around two or more adjacent implants than around single implants in both the control and the test group. Not much is written about the difference in bone resorption around single or multiple adjacent platform switching implants. Atieh et al. (2010) stated that these implants may preserve inter-implant bone height, but they could not confirm the validity of that concept. Our results revealed that there is a strong tendency that around two or more adjacent platform-switched implants peri-implant bone is better preserved than around conventional implant-abutment connected implants, albeit that bone resorption still is apparently less when neighbouring natural teeth keep up the dental bone pick. Our study was not powered for a subgroup analysis, thus no conclusive conclusion could be drawn.

With a significant difference in bone resorption as observed in our study, a difference in clinical parameters might be expected. However, we did not detect a difference in clinical parameters. This observation is in accordance with the results of the histological study by Canullo et al. (2011a). The latter authors concluded that switching and traditional platform implants had similar histological and soft tissue features, despite different bone level changes. Furthermore, Dellavia et al. (2011) concluded that platform switching apparently did not affect the inflammatory cellular and molecular pattern around the implant-abutment connection which is held responsible for bone loss in this area.

The implants applied in our trial had an implant-abutment diameter difference in horizontal dimension of 0.35 or 0.40 mm. Atieh et al. (2010) reported that subgroup analyses showed that an implant-abutment difference $\geq$ 0.4 mm was associated with a more favourable response. A bigger mismatch is often caused, as in the current study, by the use of a wider diameter. It has been speculated that the findings of reduced bone loss accompanying a larger implant-abutment difference may be due to an increased implant diameter rather than to the platform (Enkling et al. 2011). However, the study of Canullo et al. (2011b) on the impact of implant diameter of platform-switched implants clearly concluded no relation to bone resorption. When we compared the single 4 mm diameter implants with single 5 mm implants, indeed a tendency of higher bone loss was present, but by far did not reach significancy. Atieh et al. (2010) did not consider the vertical dimension of the platform-switch. In the implants we used the implant-abutment connection is 0.09 and 0.11 mm (depending on the diameter) above the outermost margin of the collar of the implant, so when placed at bone level, as in the current study, the implant-abutment connection is slightly higher. From the study of Cochran et al. (2009) we know that the least bone resorption was shown with the platform-switch situated 1 mm above the alveolar crest. So, the design of our platform-switched implants in vertical dimension might have contributed to the favourable results. Conversely, Veis et al. (2010) reported the least bone resorption when implants were placed subcrestally. Obviously from these contrasting results, more comparative studies to the different designs (in horizontal and vertical dimension) and level of placement of platform-switched implants are needed.

The inter-proximal bone level changes in this study were only measured in vertical dimension on the peri-apical radiographs, although bone resorption in horizontal extension also might have occurred. Analysis of the radiographs was done in consensus with most studies reported in the literature as the horizontal dimension is very difficult to measure. Up to now, only one study about platform switching measured the marginal bone level changes in both the vertical and horizontal dimension on digital orthopantomographs (Enkling et al. 2011).

We would have expected to find mucosal thickness before implant placement to be a predictor for crestal bone resorption, as a thin biotype has been shown to be more susceptible to marginal tissue recession and alveolar bone loss (Müller et al. 2000, Linkevicius et al. 2010, Lee et al. 2011). It could be that the number of implants placed in this study was too low to assess the role of the possible confounder mucosal thickness.

In conclusion, 1 year after loading inter-proximal bone levels were better maintained around short implants restored according to the platform switching concept. This study suggested that crestal bone resorption may be reduced by platform switching. However, to find the perfect platform switching design comparative studies to the different designs and level of placement are needed.

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Address:
G. Telleman
Department of Oral and Maxillofacial Surgery
University Medical Center Groningen
P.O. Box 30.001, 9700 RB Groningen, The Netherlands
E-mail: g.telleman@umcg.nl

Clinical Relevance

Scientific rationale for the study: Especially in short implants it is important to preserve peri-implant bone. Platform switching was introduced to limit crestal bone resorption, which is particularly relevant in short implants as these implants might develop greater compressive stress in their coronal region, when compared with longer implants. This study was conducted to assess whether platform switching indeed resulted in less peri-implant bone loss around short implants.

Principal findings: Platform switching resulted in less inter-proximal bone loss of short implants. Around two adjacent implants significantly more bone resorption was observed than around single implants.

Practical implications: Platform switching (mismatch 0.35–0.40 mm) helps maintaining inter-proximal bone levels around short implants in the posterior region.